Impacts and Extinctions

Chapter 14

Learning Objectives

- **Know the difference between asteroids, meteoroids, and comets**
- **Understand the physical processes associated with airbursts and impact craters**
- **Understand the possible causes of mass extinction**
- **Know the evidence for the impact hypothesis that produced the mass extinction at the end of the Cretaceous Period**
- **Know the likely physical, chemical, and biological consequences of impact from a large asteroid or comet**
- **Understand the risk of impact or airburst of extraterrestrial objects and how that risk might be minimized**

Earth's Place in Space

Born from the wreckage of stars,

compressed to a solid state by the force of its own gravity, mobilized by heat of gravity and radioactivity,

clothed in its filmy garments of air and water by the hot breath of volcanoes,

shaped and mineralized by 4.6 billion years of crustal evolution,

warmed and peopled by the Sun,

this resilient but finite globe is all our species has to sustain it forever.

Preston Cloud, geologist, 1978

Earth's Place in Space

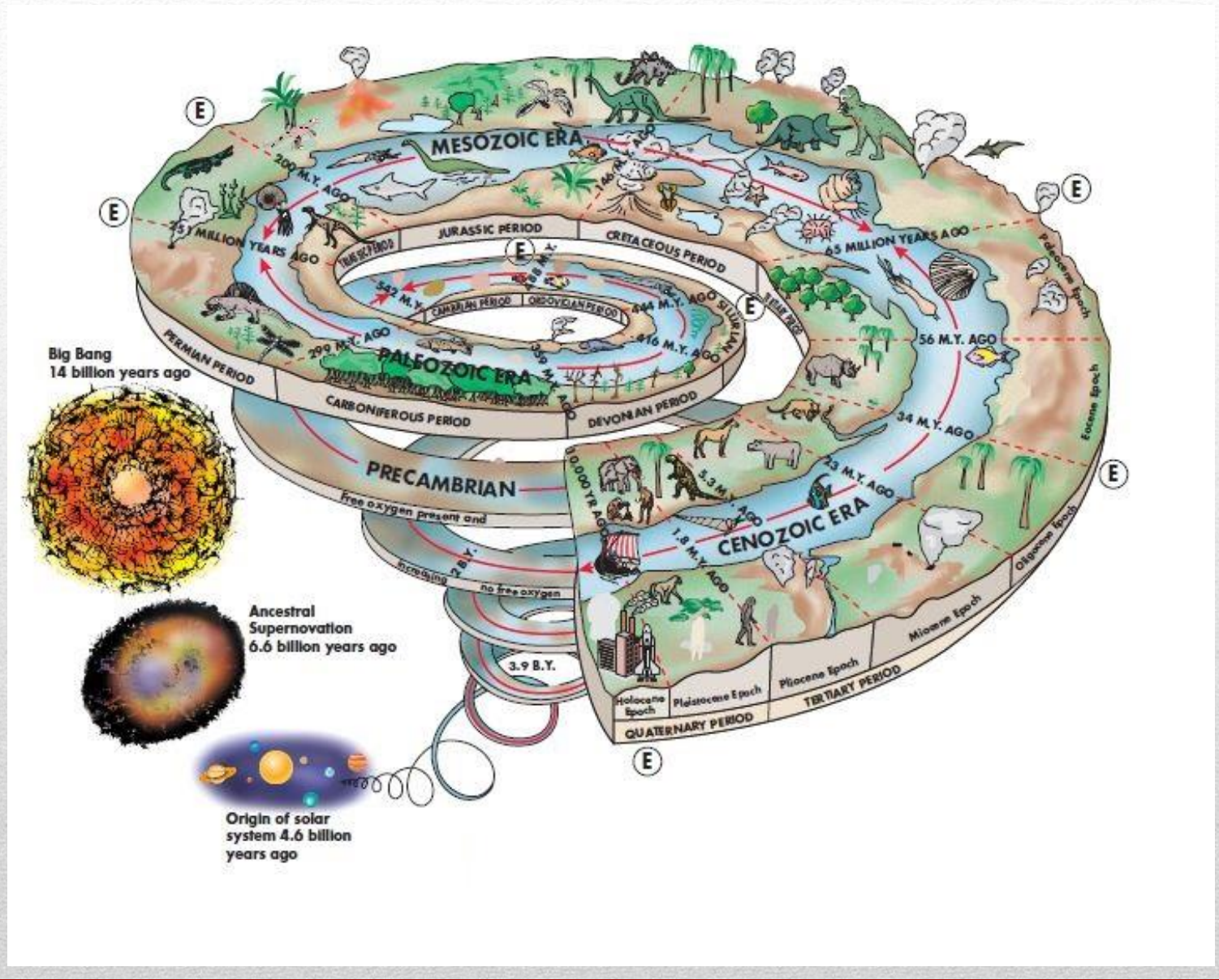
- The cloud refers to the origin of the earth – 4.6 million years ago
- We can go back further – 14 billion years to the start of the universe – The Big Bang
- The first stars formed within the first billion years, and they are still forming today
  - A star's lifetime depends on its mass – large stars have higher internal pressure and burn up quicker than small stars
  - Our sun should last around 10 billion years – thus it is a "middle-aged" star.

Earth's Place in Space

- When a star dies:
  - It is spectacular: it forms a supernova
    - A *supernova* occurs when the star is no longer capable of sustaining its mass and collapses inward
    - Results in a high-energy explosion that scatters its mass into the void of space creating a vast *nebula*
    - Gravity takes over and within the nebula matter begins to collapse back inward and new stars are born in what is called a *solar nebula.*
    - Our sun was formed from such nebula 5 billion years ago

Earth's Place in Space

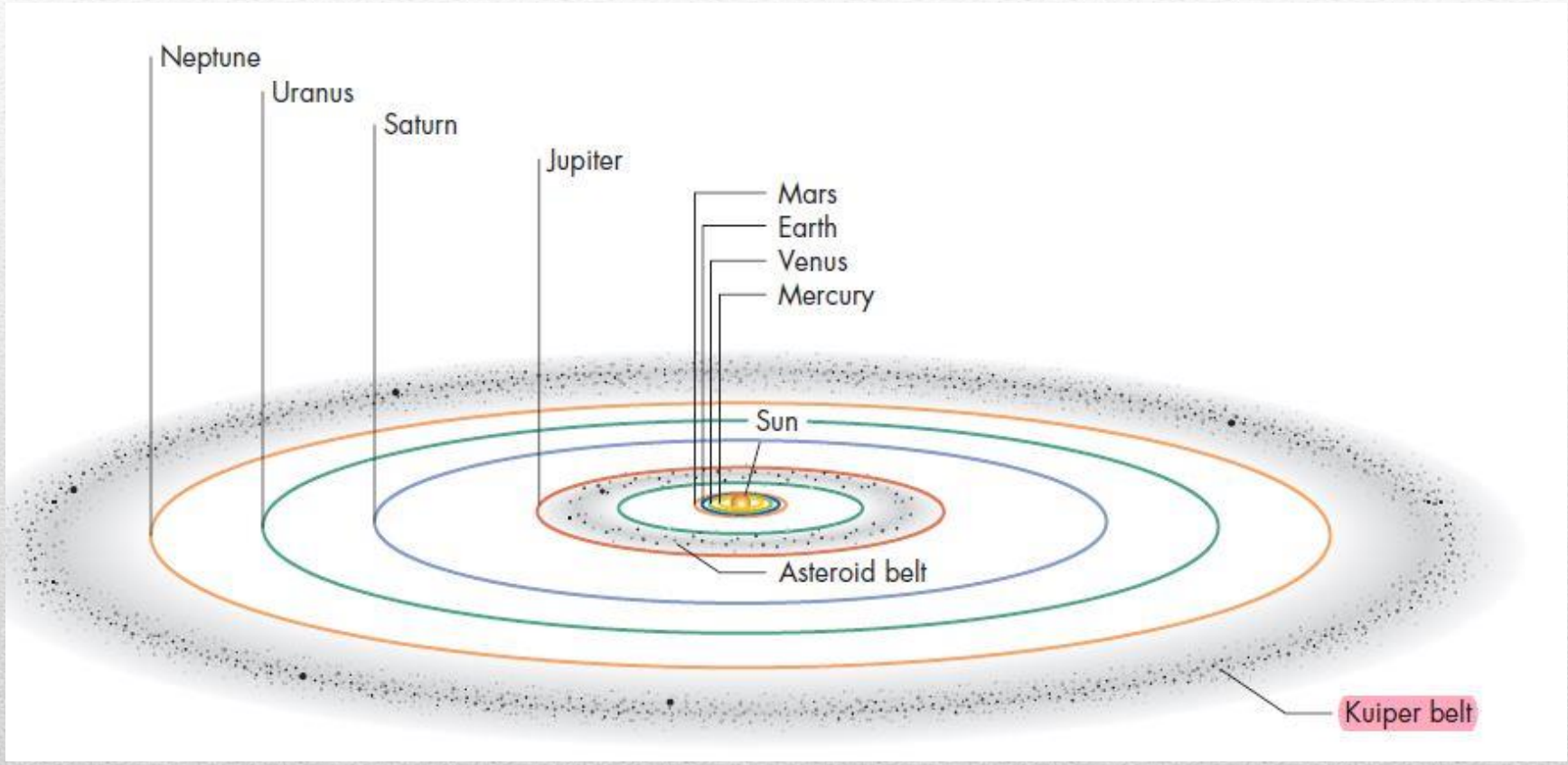
- As the sun grew, using 99.8% of the matter in the solar system and the solar nebula condensed
- Solar orbit rings began to form much like those around Saturn
- The largest, densest particles attracted to other particles to form the planetary system we have today
- All the planets were bombarded by extraterrestrial objects
  - One large one object ratcheted off the earth to become our moon.
- Around 4.6 billion years ago, the basic solar system was formed including the earth
- There were still bombardments but not as many.


MESOZOIC ERA
200 M.Y. AGO
65 MILLION YEARS AGO
JURASSIC PERIOD
CRETACEOUS PERIOD
TRIASSIC PERIOD
542 M.Y. AGO
CAMBRIAN PERIOD
ORDOVICIAN PERIOD
444 M.Y. AGO
SILURIAN PERIOD
416 M.Y. AGO
299 M.Y. AGO
PALEOZOIC ERA
PERMIAN PERIOD
CARBONIFEROUS PERIOD
359 M.Y. AGO
DEVONIAN PERIOD
PRECAMBRIAN
Free oxygen present and increasing
2 B.Y.
no free oxygen
3.9 B.Y.
Big Bang
14 billion years ago
Ancestral
Supernovation
6.6 billion years ago
Origin of solar
system 4.6 billion
years ago
Paleocene Epoch
56 M.Y. AGO
Eocene Epoch
34 M.Y. AGO
23 M.Y. AGO
Oligocene Epoch
5.3 M.Y. AGO
10,000 YR AGO
1.8 M.Y. AGO
CENOZOIC ERA
Miocene Epoch
Pliocene Epoch
TERTIARY PERIOD
Holocene Epoch
Pleistocene Epoch
QUATERNARY PERIOD
E

Asteroids, Meteoroids, and Comets

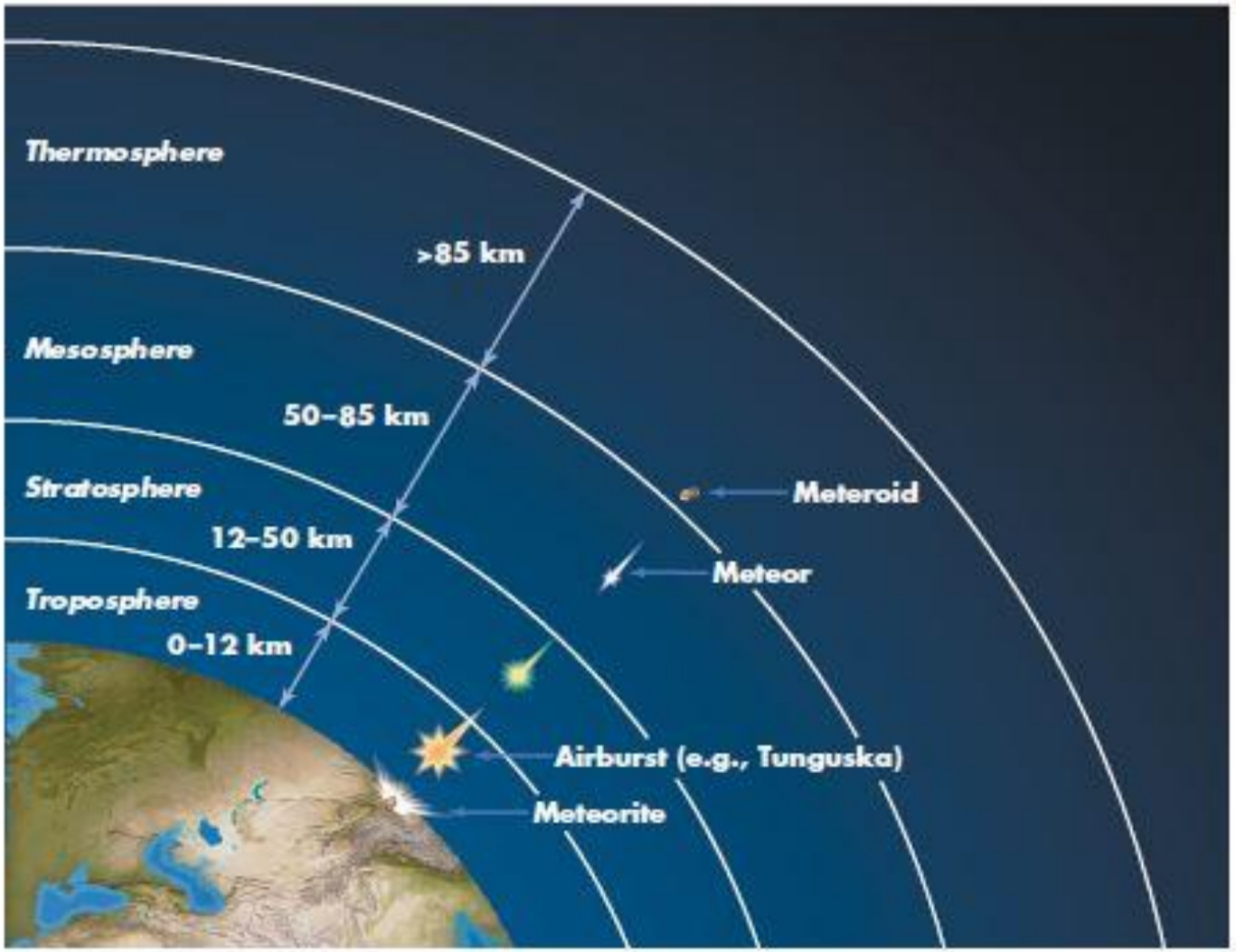
- **Trillions of particles found throughout the solar system**
  - **Asteroids –** diameter of 30 ft. to 620 miles.
    - Found in the asteroid belt between Mars and Jupiter
  - **Meteoroids** – created is asteroids collide, range in size from dust size to a few meters in diameter
    - They are called shooting stars when they streak across the sky at night
    - Occurring in large numbers creates a meteor shower
  - **Comets** – distinguished from meteoroids and asteroids by their glowing tail of gas and dust
    - Range in size from a few meters to a few hundred kilometers.
    - Composed of a rocky core surrounded by ice and covered in carbon-rich dust

Solar System and Asteroid Belt



Airbursts and Impacts

- When any one of these orbiting “rocks” enters the Earth’s atmosphere, it will travel at range of 27,000 to 161,000 mph.
- The composition of the “rock” various from carbonaceous material to native materials such as iron and nickel
- Regardless of what they are made of or where they have come from, when they intersect the Earth’s orbit and enter our atmosphere, remarkable changes happen
  - They heat up from friction with the atmosphere, producing a great light
  - It a meteor hits the earth, it becomes a meteorite
    - If they don’t burn up on impact, they will leave a **impact crater**
    - If they don’t hit the earth, they can explode in a giant **airburst**

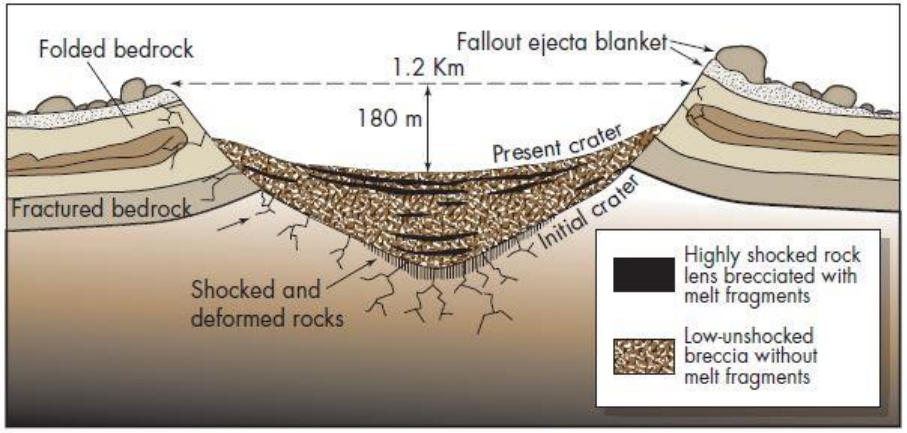

Thermosphere
>85 km
Mesosphere
50–85 km
Stratosphere
12–50 km
Troposphere
0–12 km
Meteoroid
Meteor
Airburst (e.g., Tunguska)
Meteorite

Impact Craters

- Obvious evidence for impacts are the craters left behind
  - Barringer Crater in Arizona – most famous
    - Known as the "Meteor Crater"
    - Around the edge of the crater is debris called an *ejecta blanket*, this was blown out on impact
    - Its not as deep today, since much of the rock blown out has fallen back in
    - Rocks hit by the asteroid were shattered, deformed or cemented together, these are called *breccia*
  - Two types of craters
    - Simple craters – small with a few kilometers in diameter
    - Complex impact craters – start out like simple craters, but grow in size as the rim collapses in on the crater

Barringer Crater

(a)



(b)

World Impacts

- Impacts are more common on the moon for 3 reasons
  1. Most found in the ocean which are then buried by sediment or destroyed by tectonic movement
  2. Those found on land are generally subtle features that are eroded, buried, or covered with vegetation
  3. Smaller meteoroids and comets tend to burn up and disintegrate in the atmosphere
- On February 15, 2013, at a speed of 42,900 mph, the Chelyabinsk meteor crashed into the southern Ural region of Russia.
  - The light was brighter than the sun, heat from the fireball was felt by those watching it on the ground
  - It exploded in an airburst over city in a huge burst of light


ARCTIC OCEAN
Hudson Bay
CANADA
PACIFIC OCEAN
UNITED STATES
ATLANTIC OCEAN
0 250 500 Miles
0 250 500 Kilometers
Extraterrestrial impact craters
MEXICO
Gulf of Mexico
N

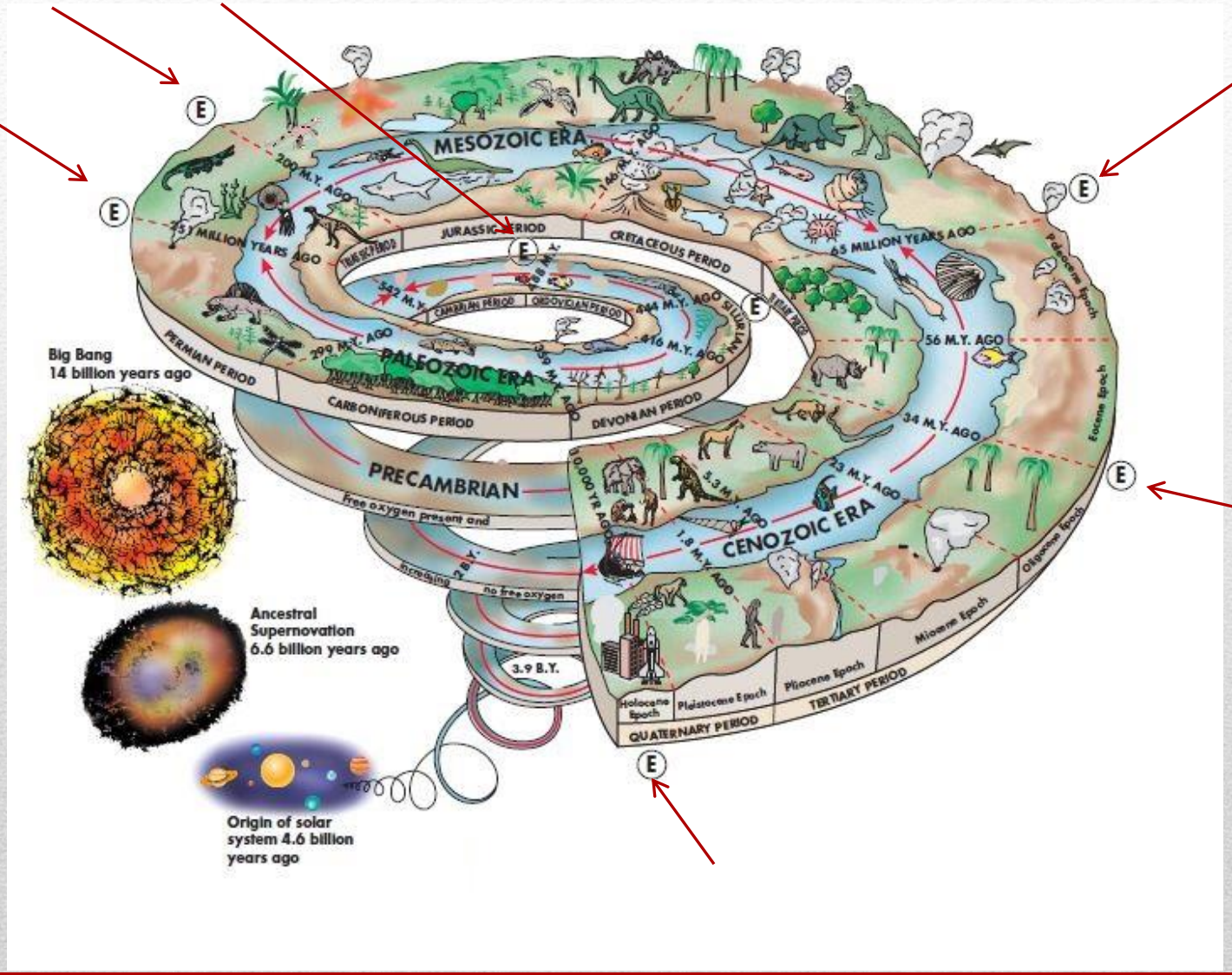
Mass Extinctions

- **Mass Extinctions**
  - Characterized by the sudden loss of large numbers of plants and animals relative to the new number of species being added
  - Geological time scale was originally based on the appearance and disappearance of various fossil species
  - Mass extinctions generally coincide with the boundaries of geologic periods or epochs of the time scale
  - The mass extinctions are thought to be caused by rapid climate change
    - This climate change can be from plate tectonics, volcanic activity, or extraterrestrial impact

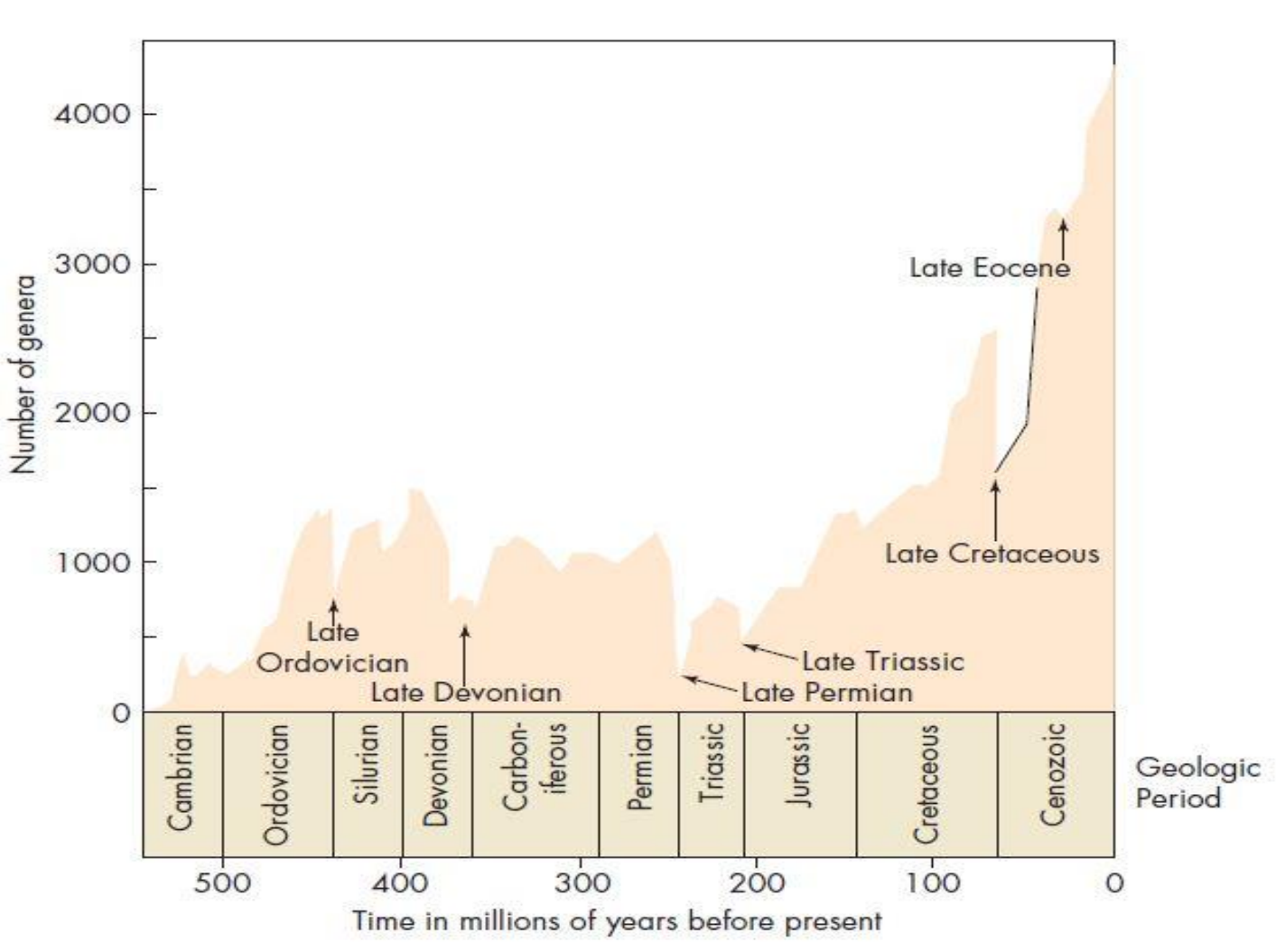
Mass Extinctions

- **Triggers of climate change**
  - Plate tectonics is generally a relatively slow process, moving the positions of the continents and thus, the habitats to other locations
    - These plate movements can cause climate change to certain areas
  - Extremely large volcanic eruptions can also cause significant change in climate by the release of basalt flood which can release carbon dioxide into the atmosphere
  - These eruptions if explosive, can release a large amount of volcanic ash, which can cause climate cooling
  - Climate change is one of the effects of extraterrestrial impacts or airburst that can cause extinctions

Five Mass Extinction Events



Mass Extinctions over Geologic Periods



Earth's Mass-Extinction Events

- **1st & 2nd – 446 million years ago – the first and second mass extinction happened near the end of the Ordovician Period**
  - 100 families of animals became extinct – coinciding with a major continental glaciation in the Southern Hemisphere
  - There were two extinctions – one from the cold and one during the warming period
- **3rd – Largest recorded mass extinction – near the end of the Permian Period – about 250 million years ago**
  - 80% to 85% of all species alive died out- may have spanned 7 million years
  - Possible cause by an impact, eruptions of Siberian of basaltic floods releasing voluminous greenhouse gasses causing climate change, sea level dropped and the assemblage of the super continent of Pangaea

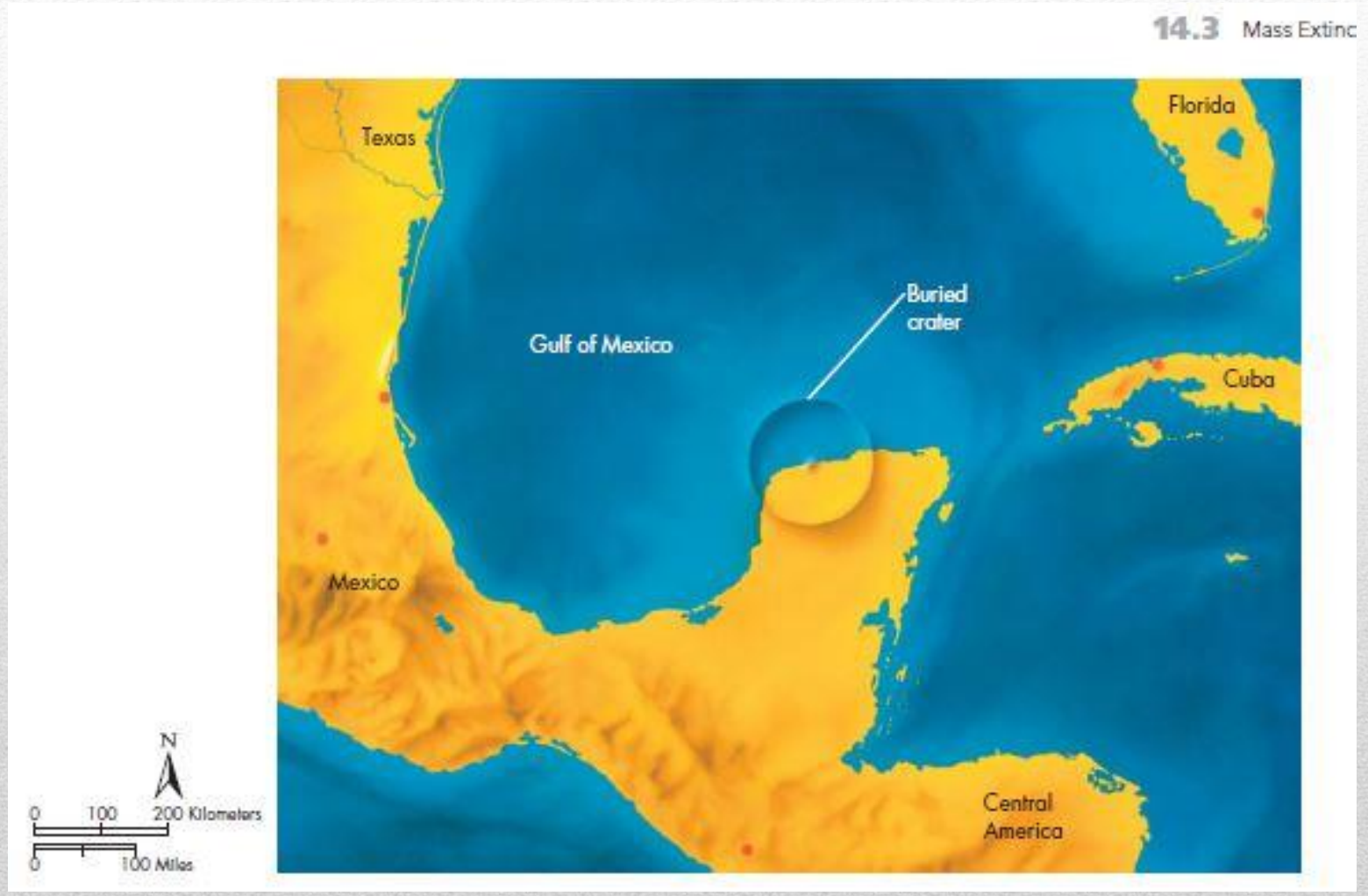
Earth's Mass-Extinction Events

- **4th– 202 million years ago – at the boundary of the Triassic-Jurassic Boundary**
  - Related to volcanic activity and climate change associated with the breaking apart of Pangaea
  - The volcanic activity released large amounts basalt and carbon dioxide increasing the earth's temperatures resulting in rapid climate change
  - Caused the extinction of plant, animals, and half the marine animals.

Earth's Mass-Extinction Events

- **5th – Mass extinction at the end of the Cretaceous and beginning of the Tertiary Periods – known as the *K-T boundary;* 64,980,000 million years ago**
  - There has been found evidence found that a giant asteroid hit Earth along the northern shore of what is now the Yucatan Peninsula
  - **This event altered Earth's history forever.**
    - Although the plant species were not necessarily effected, the planet's inhabitants largely were largely changed
    - All of the dinosaurs disappeared, including 70% of all genera and their associated species
    - Some reptiles, such as crocodiles, alligators, and turtles and some birds, plants and smaller mammals survived either by their kind of habitat or where they lived

Large Impact Carter in Mexico



Earth's Mass-Extinction Events

- Why did this extinction happen??? This is a very new theory
  - After the impact of the asteroid, there were wildfires
  - Some plants and animals were better at adapting to new climate
  - Since the dinosaurs could not adapt and died, the evolution of mammals happened
    - This included primates and humans
    - The history of this extinction was discovered by examining rocks and the mineral they are made up of, this would be iridium
    - This exploration of the rocks helped to develop the theory of the asteroid strike and the extinctions which happened after was formulated between 1980 and the discovery of the crater in 1991

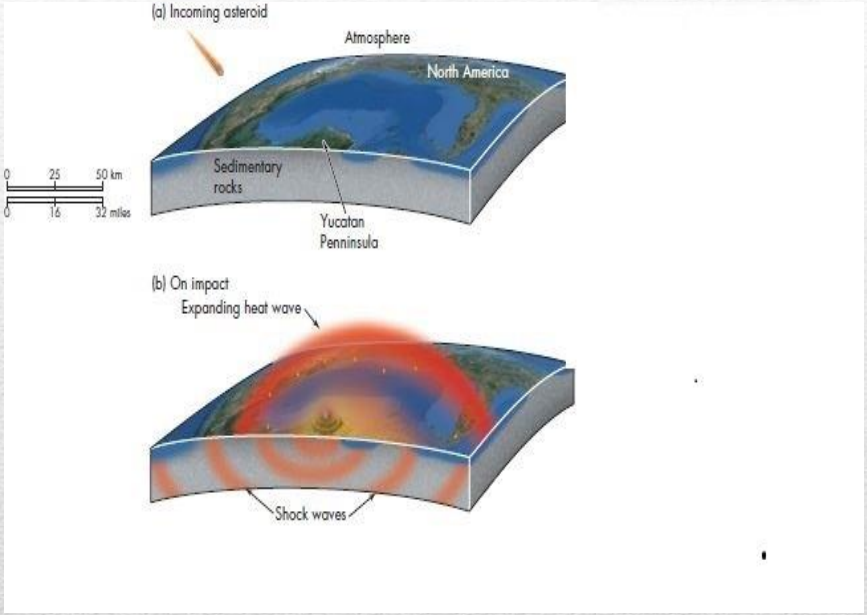
Summarizing the K-T Extinction Event

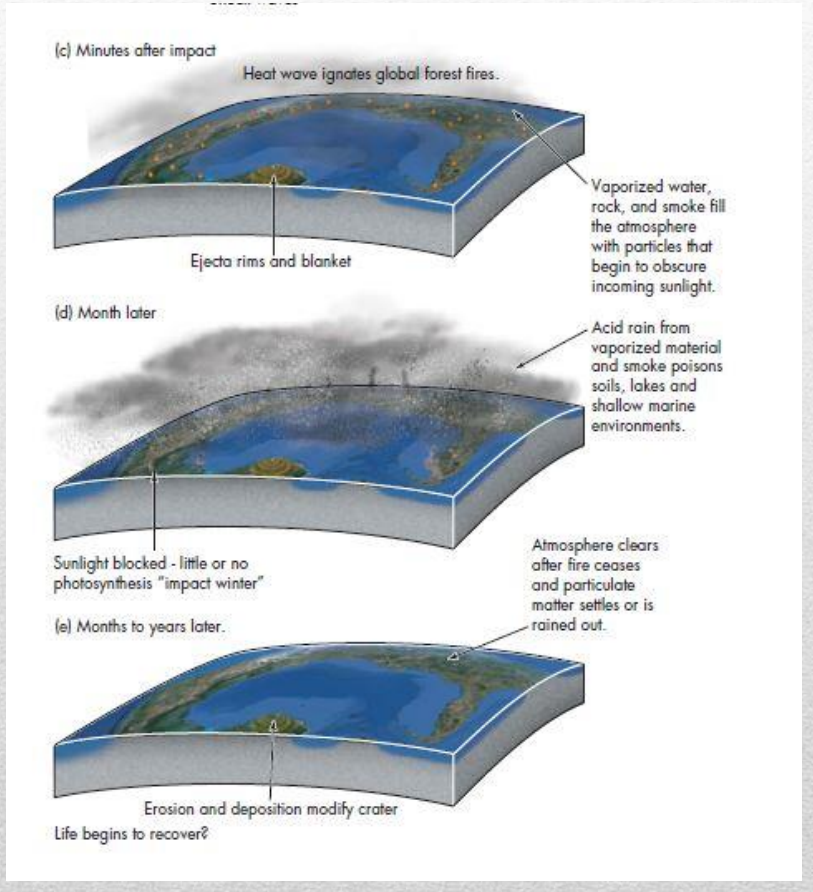
- The impact of the asteroid caused a global catastrophic killing
  - The asteroid took about a half a second to blast through the atmosphere
  - On impact the asteroid blasted a hole – about 125 miles across and 25 miles deep
  - The contact shock waves crushed rocks, melting some of them together, throwing all sorts of rock particles into the atmosphere
  - This only took about 2 seconds
  - The impact huge blanket of debris was build around the crater in those 2 seconds
  - The impact created a gigantic cloud of vaporized rocks and gases would produce and equally large fireball mushroom cloud
  - The fireball produced sufficient heat and ballistic rocks set fires around the globe and destroyed anything within miles
  - Vaporized gypsum salts produced sulfuric acid in the atmosphere

Summarizing the K-T Extinction Event

- Additional acids were added to the atmosphere as a result of burning nitrogen in the atmosphere, creating acid rain
- The acid rain would continue to fall for a long period of time after the impact
- The dust in the atmosphere circled Earth for months blocking sunlight from reaching the lower atmosphere
- Without any sunlight there was no photosynthesis on the land and in the ocean
- The acid rain was toxic to many living things in the terrestrial and shallow marine waters. This caused the food chain to virtually stop functioning
- Since part of the impact was in the ocean, the seafloor was disturbed causing huge tsunamis to race across the Gulf of Mexico and inundate parts of North America
- Wildfires ravaged southern North America, all of Central America, parts of South America, Africa, Asia, and Australia
- The climate first cooled because of lack of sunlight
- It then warmed as aerosols and carbon dioxide enhanced the greenhouse effect
- Finally, large numbers of ferns restored plant cover on the burned landscape which started to bring normality to the Earth's atmosphere

The sequence of events in the K-T event





Earth's Mass-Extinction Events

- 6th – 34 million years ago there was a mass extinction which for years scientists thought was brought on by another impact or airburst
  - At first scientists believed this extinction was due to climate change brought on by tectonic movement
  - The movement of the plates cooled the ocean currents in the Southern Hemisphere.
  - This change in the currents change the water around Antarctica would produce the Antarctic ice cap
  - Resulting in global cooling and drying in the atmosphere

Earth's Mass-Extinction Events

- **The last mass extinction is thought to happen near the end of the Pleistocene Epoch (Ice Age) or approximately 12,900 years ago**
  - The mass extinction was of the large mammals and ancient Clovis People who roamed North America during the last Ice Age
  - The extinction of the large animals was first thought by scientists to be the result of over hunting by the Clovis or climatic cooling
  - A new theory is now being consider, scientists think another large air burst happened when the asteroid exploded over North America leaving a thin layer of black dust in the air and found in rocks across the United States. This explosion started fires, created shock waves and other damaging events
  - The dust intensified the climate change, increasing the Ice Age
  - Within the next 200 hundred years, all these huge animals and the Clovis people would disappear from the face of the earth
  - This is still theory, scientists are still investigating this theory

Linkages with Other Natural Hazards

- The impact or airburst of an asteroid or comet are a direct cause for a number of natural hazards
  - Tsunamis
  - Wildfires
  - Earthquakes
  - Mass Wasting
  - Climate Change
  - Volcano Eruptions
  - Seismic waves

Minimizing the Impact Hazard

- What are the **related risks of impacts and how can they be reduced**
  - The is risks are related by both the probability that it might occur and the consequences should it take place
    - If there was an impact or an airburst of a huge object-its consequences would be catastrophic
    - This type of event, although have usually happened millions of years apart
    - Events of lesser intensity happen around the world daily, but because they are much smaller, there are less effects to deal with
    - The probability that you will be hurt by one of the events should they happen is very low since they don’t happen too often
    - There is a bigger probability that you will be in a car accident

Natural Service Functions of Wildfires

- Wildfire, although threatening to human life and property, can be beneficial to the ecosystems of the earth.
  - Benefits to the soil
    - Increase to the nutrient content of the soil and leave an accumulation of carbon on the surface in the form of carbon
  - Benefits to plants and animals
    - By reducing the number of individuals of species of plant in a given area the result may be beneficial to the plant community
    - By having a fire, a dominant vegetation may be helped by the occurrence of wildfires
    - Burning plant material recycles nutrients by quickly decomposing organic matter and allowing new plants to grow

Minimizing the Impact Hazard

- **How can we reduce the impact hazard?**
  - Identify nearby objects in our solar system
  - Categorization of these objects which could cross the earth's path has already begun
  - Programs such as ***Spacewatch*** and ***Near-Earth Asteroid Tracking*** **Project (Neat)** are in place to watch the skies

Minimizing the Impact Hazard

- **The Neat Project**
  - The Neat Project uses digital imaging programs to measure which objects is moving towards the earth fastest
  - Tracking this objects is difficult since many of the objects will not return to visibility for many decades or hundreds of years
  - This is good news because it could be several hundreds to thousands of years before there is a danger of this object coming close to the year, much less hitting the earth
  - There are about 20 million extraterrestrial bodies in a near-earth orbit which could potentially impact the earth, but this would be weal and probably would explode before they hit the earth

Minimizing the Impact Hazard

- Creation of the Torino Impact Hazard Scale
  - Developed by NASA as a technical review process for the predictions of earthquakes and pending impacts
  - This would be a survey to be used for classifications of potentially hazardous bodies and follow them
  - This survey would track this objects in case they look like they are going to enter the atmosphere
  - If an object is found to be heading towards the earth the plans to eliminate the object is limited
  - A scale was developed to explain how hazardous the impact might be and what action should be taken

The Torino Impact Hazard Scale

No Hazard	0	Low collision hazard or object will burn up in atmosphere
Normal	1	Object will pass near Earth with collision extremely unlikely
	2	Somewhat close encounter; collision unlikely and does not merit public attention
Merits Attention by Astronomers	3	Close encounter with localized destruction possible; merits public attention if collision less than a decade away
	4	Close encounter with regional destruction possible; merits public attention if collision less than a decade away
	5	Close encounter with serious, but uncertain, regional destruction threat; merits contingency planning if less than a decade away
Threatening	6	Close encounter with serious, but uncertain, global catastrophe threat; merits contingency planning if less than three decades away
	7	Very close encounter with unprecedented, but still uncertain, global catastrophe threat; merits international contingency planning if less than a century away
	8	Collision will occur with object capable of localized destruction on land or tsunami if offshore; once every 50 to 100 years
Certain Collisions	9	Collision will occur with object capable of regional devastation or major tsunami; once every 10,000 to 100,000 years
	10	Collision will occur with object capable of global climatic catastrophe that threatens civilization; once every 100,000 years or more